

**Genetic and environmental factors influencing milk, protein and fat yields of pasture-based dairy cows in Tasmania, Australia**

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**Running head:** Milk yield and composition in grazing cows

**Abstract.** The objective of this study was to provide an update on milk production performance, heritability, genetic and phenotypic correlations among production traits which are valuable for management, breeding and selection decisions in pasture-based dairy systems. The study utilised a total of 106,990 lactation records of Holstein-Friesian (FF), Jersey (JJ) and their crossbreds (HF) from 428 Tasmanian dairy herds collected between 2000 and 2005. The data were analysed using the least squares approach with a general linear model and restricted maximum likelihood approach with a linear animal model. Results indicated highly significant ( $P < 0.01$ ) effects of breed, herd size, cow's parity, season and year of calving on milk, protein and fat yields. Average milk and protein yields per cow per lactation were highest in the FF breed (5,212 litres and 171 kg, respectively) and lowest in the JJ breed (3,713 litres and 143 kg, respectively). FF cows also produced 13.5kg more milk fat than JJ and HF cows. Furthermore, milk, fat and protein yields were highest for cows calving during spring and lowest for autumn-calving cows. It was also evident that cows in very large herds ( $>1110$  cows/herd) out-produced those in smaller herds. Heritability was highest for milk yield and lowest for somatic cell count ranging from 0.28 to 0.41. Genetic and phenotypic correlations between milk, fat and protein yields ranged from 0.41 to 0.85, and 0.66 to 0.92, respectively. On the other hand, genetic and phenotypic correlations between the log of somatic cell count and the production traits ranged from 0.03 to 0.09 and -0.03 to -0.05. We conclude that breed, herd size, parity, season and year of calving were among the main factors correlated with the productivity of dairy cows in Tasmania and adjustments for these factors would be mandatory for any unbiased comparison of lactation performance within and between pasture-based dairy production systems. The practical application of this information would be valuable to dairy farmers for decisions related to breeding, selection and management of their herds.

**Keywords:** Pasture-based cows, Holstein-Friesian, Genetics, Tasmania, Milk, Protein, Fat

## 41 Introduction

42 The dairy industry in Australia is very important to the agricultural sector of the economy.  
43 With an ex-factory value of \$9.1 billion and farm gate value of \$3.2 billion, it is the third  
44 biggest rural industry behind beef and wheat (Dairy Australia 2006). Milk production is  
45 concentrated in the South-Eastern corner of Australia, with the states of Victoria, Tasmania  
46 and South Australia accounting for 78% of the national output. Like in Victoria, dairying in  
47 Tasmania is characterised by seasonal, low-input, pasture-based milk production reliant on  
48 family labour. However, ninety percent of dairy farms use supplementary feeds such as hay,  
49 silage and concentrate to augment seasonal shortages in grass production (Dairy Australia  
50 2006). Deregulation of the production sector in 2000 as well as widespread drought in 2002-  
51 03 led to substantial restructuring such as reduction in farm numbers, high cost of grain  
52 supplements and increased herd sizes (ABARE 2003). Although the Holstein-Friesian (FF)  
53 constitutes about 70% of the dairy breeds in Tasmania, there are growing numbers of other  
54 breeds including the Jersey (JJ), Friesian and Jersey crossbreds (FJ), Guernsey (GG), Ilawara  
55 (II) and Australian Reds (RR). Climatic factors also differ between dairy locations. Although  
56 milk production from Tasmania constitutes a small proportion (7%) of the national output,  
57 nearly 90% of the milk produced in Tasmania is processed for export (Dairy Australia 2006),  
58 compared to 30-40% in New South Wales (NSW), Queensland and Western Australia  
59 (Edward 2005). Industry statistics also indicates that the Tasmanian dairy industry is growing  
60 at rates comparable to those of major dairy producing states of Australia. Tasmania's typical  
61 climate offers an opportunity for year round-milk production, where precipitation is not  
62 limiting. Consequently, dairy production in Tasmania will continue to play a significant role  
63 in both domestic and overseas export of milk products.

Milk is synthesised by secretory cells in the mammary glands of lactating animals primarily as nutrition for the young. Factors affecting milk production in dairy animals include genetic (Tekerli *et al.* 2000), environmental and management factors, (Msanga *et al.* 2000). Several studies (Madgwick and Goddard 1989, Dobos *et al.* 2001; Wales *et al.* 2006) have identified factors affecting milk production of dairy cows in Victoria and other parts of Australia. Tasmanian dairy farmers are one of the most efficient in pasture-based dairying (Dairy Australia (2004). However, except for some performance indicators of the industry compiled by the Department of Primary Industry and Water (DPIW 2005) see (Appendix 1) and Dairy Australia (2005), there is paucity of recent information on the key driving factors influencing dairy cattle performance in Tasmania. Therefore the objectives of this study were; to characterise and quantify the milk production of pasture-based dairy cows in Tasmania as influenced by breed, parity, location, herd size, season, parity, year and their interactions; to identify the critical management factors underpinning milk and milk component yields and to estimate the heritability of production traits and somatic cell count.

## **MATERIALS AND METHODS**

### *Site and climatic conditions*

Tasmania is Australia's southern-most state with a land mass of 68,000 sq km, located at latitude 42° South, longitude 147° East and lies completely within the temperate zone. The summer, autumn, winter and spring seasons are in the months of December-February, March-May, June-August and September-November, respectively. Average maximum temperatures are 21<sup>0</sup>C (70<sup>0</sup> F) and 12<sup>0</sup>C (54<sup>0</sup> F) in summer and winter respectively. Summer is warm with sunny days and mild evenings, while autumn is cool with frosty nights and occasional storms. Winter is mild with occasional snows on the higher mountain peaks. The annual rainfall varies from 626 millimeters (25 inches) in the south to 2,400 millimeters (94 inches) on the

North-West Coast. The prevailing weather pattern creates a rain shadow in the west to east direction leaving the East coast always warmer and drier than the rest of the state.

#### *Data source and editing*

The data used in this study were obtained from TasHerd, which is the contracted herd recording agency for the Australian Dairy Herd Improvement Scheme (ADHIS) in Tasmania. The data were from 428 dairy herds and consisted of 130, 366 observations on total milk, fat, protein and somatic cell count (SCC) yield records of purebred Holstein-Friesian , Jersey , Guernsey, Illawarra, and Australian Reds as well as crosses of Holstein-Friesian and Jersey cows of different ages, season of calving, parity, and lactation length.

Two data sets were created. **DATA1** which explored non-genetic factors affecting production traits used records from three breeds namely; FF, JJ and FJ, these being the predominant breeds in Tasmania. Small data size and incomplete records on the other breeds in regional data made genetic computation difficult, hence only records comprising of the FF breed were utilised for genetic analysis in **DATA2**. For each cow, records of cow number, birth date, calving date, 305-day milk yield, protein and fat yields, milksolids yield, lactation length, and herd number were available. This information was used to determine cow age, calving season, parity, and herd sizes. Daily milk, fat and protein yields were obtained by dividing the total milk and milk component yields by the lactation length. Percentage milk fat and milk protein were obtained by dividing total fat and total protein yields by total milk yield. Lactations with incomplete records i.e. missing birth date, calving date, milk or milk component yields were deleted. Records of cows with lactation length <100 days were also excluded from the analyses. **DATA1** finally consisted of 106, 990 records from 428 herds, over six production years. Parities greater than four were pooled as parity5. To protect farm identities, coded herd

numbers and postcodes of dairy farms were used. The final data set consisting of thirty postcodes was divided into 6 subsets, herein referred to as locations, based on existing local council areas. For instance, herds with postcodes 7260-7265 were grouped into the North-East location (Table 1). Herds were classified to correspond with the state's average herd size of 250 cows. Herd groups were below, similar to, twice and four times the state's average herd size. The four herd size classes were; 1-210, 211-575, 576-1100 and larger than 1100 cows per herd designated as small, medium, large and very large herds, respectively. For DATA2, additional data omitted from the analysis were all breeds except FF, cows with parity >5 and 305 day milk yield <1,200 L leaving a total of 65,914 records. Parity >2 were pooled and labelled as parity3. Dairy farm statistics of Tasmania is presented in Appendix 1. Least square means and summary statistics of the traits for DATA1 and DATA2 are presented in Tables 1 and 3 respectively.

#### *Statistical analysis*

*DATA1.* General linear models (GLM) procedure in SAS (SAS 2002) was utilised to compute least square means, standard errors (s.e.) and coefficient of variation (c.v.) of the traits. Location, herd size, breed, calving year, calving season and parity were fitted as fixed effects while age and lactation length were included as covariates. All possible interactions between the fixed effects were included in the original model, but non-significant interactions were dropped from the final model. The model used to describe each lactation record was:

$$Y_{ijklmnopq} = \mu + L_i + H_j + S_k + Y_l + B_m + P_n + (BS)_{km} + (BY)_{lm} + (SP)_{kn} + (BP)_{mn} + (PSY)_{nkl} + b_1(L_{ijklmno} - \bar{LL})^2 + b_2(A_{ijklmnop} - \bar{A})^2 + e_{ijklmnopq} \quad 1$$

where  $Y_{ijklmnopq}$  is the  $ijklmnopq$ th observation of the dependent variables (milk, fat and protein yields and log of somatic cell count), with fixed effects  $L_i$  of  $i^{th}$  location ( $i=1,2..6$ );  $H_j$  of  $j^{th}$  herd size ( $j=1,2...4$ );  $S_k$  of  $k^{th}$  season of calving ( $k=1,2...4$ );  $Y_l$  of  $l^{th}$  year of calving ( $l=1,2...6$ );  $B_m$  of  $m^{th}$  breed ( $m=1,2...3$ ) and  $P_n$  of  $n^{th}$  parity ( $n=1,2...5$ ). First order interaction effects were  $(BS)_{km}$  of breed and season,  $(BY)_{lm}$  of breed and year,  $(SP)_{kn}$  of season and parity and  $(BP)_{nm}$  of breed and parity and second order interaction effects of season, year and parity  $(PSY)_{nkl}$ . There was a total of 7, 11, 13, 9, and 81 combinations of BS, BY SP, BP and PSY subclasses respectively. The model terms  $b_1(L_{ijklmno} - \bar{LL})^2$ , and  $b_2(A_{ijklmnop} - \bar{A})^2$  represent the fitting of lactation length (LL) and age of the cow (A) as covariates with  $b_1$  and  $b_2$  as their partial regression coefficients respectively;  $\mu$  is overall mean and  $e_{ijklmnopq}$  is the random sampling error with mean zero and variance  $\sigma_e^2$ . Means were compared using the least significant difference technique of SAS GLM procedure.

**DATA2.** In the genetic analysis of milk, fat, protein and somatic cell count, Y, P, S H and YS interaction (as previously defined), were fitted as fixed effects, while cow was used as a random effect. Age at calving (Age) and lactation length (LL) were included as covariates in all analyses. All traits were first analysed with a univariate animal model in ASReml (Gilmour *et al.* 2006) to obtain start up values for the covariance structures in subsequent analyses. A single multivariate analysis using an animal model was performed in ASReml to estimate heritabilities as well as phenotypic ( $r_p$ ) and genetic ( $r_G$ ) correlations of production traits (milk, fat and protein yields) with their associated standard errors (Table 4), while the log- transformed values of somatic cell count were analysed as a univariate factor.

The animal model is:

$$y_{ij} = \mu_i + Y_{jk} + P_{il} + S_{im} + YS_{ikm} + H_{in} + \beta_1 LL_j + \beta_2 Age_j + a_{ij} + e_{ij} \quad 2$$

$$Y_{ijklmnop} = \mu + H_i + S_j + Y_k + P_l + (YS)_{jk} + b_1(L_{ijklm} - \bar{L})^2 + b_2(A_{ijklmn} - \bar{A})^2 + a_{ijklmno} + e_{ijklmnop}$$

163

164 where  $Y_{ijklmno}$  represents the dependent variables total milk, fat, protein and log of SCC,  $\mu$  is  
165 the population mean,  $H_i$ ,  $S_j$ ,  $Y_k$ ,  $P_l$  and  $YS_{jk}$ , are the fixed effects of the variables on  $i^{th}$  herd  
166 ( $H=1,2,...216$ ),  $j^{th}$  calving season ( $S= (1,2,...4)$ ),  $k^{th}$  calving year ( $Y=1,2 ...6$ ),  $l^{th}$  parity  
167 ( $P=1,2,...3$ ), and  $jk^{th}$  first order interaction of calving year and season ( $YS= 1,2,...46$ ),  
168 respectively,  $b_1$  and  $b_2$  are the regression coefficients of lactation length ( $L$ ) and age at calving  
169 ( $A$ ) respectively,  $a_{ijklmn}$  is the random additive genetic effect and  $e_{ijklmnopj}$  is the random residual  
170 error. A pedigree file tracing ancestry to the last 5<sup>th</sup> generation was included in the analysis of  
171 DATA2.

172

173 In matrix notation the model can be written as

174

175 
$$y = \mathbf{X}b + \mathbf{Z}a + \mathbf{W}p + e,$$

176

177 where  $y$  is the vector of observations,  $b$  is the vector of fixed effects  $H_i$ ,  $S_j$ ,  $Y_k$ ,  $P_l$  and  $YS_{jk}$ ,

178  $b_1LL_j$  and  $b_2Age_j$ ,  $a$  is the vector of  $a_{ij}$  ~~additive genetic effects~~ ~~random animal effects~~,  $p$  is the

179 vector of permanent environmental effects for cows with 305 day records,  $e$  is the vector of

180 random residual effects and  $\mathbf{X}$ ,  $\mathbf{Z}$ , and  $\mathbf{W}$  are the incidence matrices which relate records to

181 fixed, animal and permanent environmental effects respectively. It is assumed that the

182 permanent environment and the residual effects are independently distributed with means of

183 zero and variance  $\sigma_{pe}^2$  and  $\sigma_e^2$  respectively. The variances of the random additive, permanent

184 environment and random error effects are  $\mathbf{A}\sigma_a^2$ ,  $\mathbf{I}\sigma_{pe}^2$  and  $\mathbf{I}\sigma_e^2 = \mathbf{R}$  and variance of  $y$

185 
$$\text{var}(y) = \mathbf{ZAZ}'\sigma_a^2 + \mathbf{WI}\sigma_{pe}^2\mathbf{W}' + \mathbf{R}$$

186

187

188

189



190 with  $\begin{pmatrix} a \\ p \\ e \end{pmatrix} \equiv$

191  $\begin{pmatrix} G \otimes A & 0 & 0 \\ 0 & I\sigma_p^2 & 0 \\ 0 & 0 & U \end{pmatrix}$

192 where  $G$  is covariance matrix of the random regression coefficients, assumed to be the same  
 193 for all cows;  $A$  is additive genetic relationship matrix among the animals;  $\otimes$  is Kronecker  
 194 product function (Searle 1982);  $I$  is identity matrix; and  $U$  is unstructured matrix with  
 195 elements that define the traits.  
 196

197 The mixed model equation for this model would be  
 198

199  $\begin{pmatrix} X'R^{-1}X & X'R^{-1}Z & X'R^{-1}W \\ Z'R^{-1}X & Z'R^{-1}Z + G^{-1} \otimes A^{-1} & Z'R^{-1}W \\ W'R^{-1}X & W'R^{-1}Z & W'R^{-1}W + Ik \end{pmatrix} \begin{pmatrix} \hat{b} \\ \hat{a} \\ \hat{p} \end{pmatrix} = \begin{pmatrix} X'R^{-1}y \\ Z'R^{-1}y \\ W'R^{-1}y \end{pmatrix}$

200 Where  $k = I/\sigma_p^2$  was assumed constant across traits.  
 201  
 202

## 203 RESULTS

### 204 DATA

205 Least squares means estimates using Model 1 are presented in Tables 1 and 2. Milk, fat and  
 206 protein yields were significantly different ( $P < 0.01$ ) between cattle breeds, parity and season  
 207 of calving except for fat yield which did not differ between the Jerseys and crossbred cows.  
 208 The model fitted explained 40-43% of the variations due to environmental and management  
 209 factors. Lactation length accounted for about 19.3% of the total sums of squares. The other

factors influencing productivity were herd size, location, and cow age in order of decreasing magnitude except for fat and protein yields where parity had greater influence than genotype and location.

*Calving Year.* The effect of year of calving on milk yield, milk composition and the log of somatic cell count of the cows is shown on Table 1. Total milk yield (L/lactation) was significantly different ( $P<0.01$ ) between all calving years except 2001 and 2003. Total milk yield progressively increased annually by an average of 2.5-5.7% except for a 101L decline from 2002 to 2003. Similar trends were observed for fat and protein yields. There was also a general increase in annual total milk solids of 16-21 kg from 2001 to 2005 except for 2002 and 2003. Daily yields of milk, fat, protein and milksolids also progressively increased with advances in calving year (except in 2003).

*Insert Table 1 here*

*Breed.* Milk yield was significantly different ( $P<0.01$ ) between the three breeds evaluated in this study (Table 1). Total milk, fat, protein and milksolids yields were highest in FF cows, while JJ and FJ cows had similar fat and milk solids yields. JJ cows had the least protein yield and somatic cell count. Differences between the FF and JJ in milk, fat and protein yields were 1499 L, 13 kg and 28 kg respectively. JJ and FJ cows produced 29% and 18% less milk/lactation respectively, than FF cows. Protein yield followed a similar pattern. (Table 1).

*Parity.* Parity significantly ( $P>0.01$ ) influenced all milk production parameters (Table 1). Milk, fat, protein and milksolids yields were highest in cows with parity  $>4$  and lowest in first parity cows. There was an observed increase in milk, fat, protein and milksolids yields as

parity increased from 1 to >4, while the lowest SCC was observed in parity >4 cows (Table 1). Milk yield differences between first vs second parity and second vs third parity cows were 538 L and 595 L respectively, compared with those between third vs fourth and fourth vs parity>4 cows (211 L and 193 L, respectively).. Total milksolids increased from 277 kg in primiparous cows, to 407 kg in cows with parities >4.

*Location.* The effect of location on yields of milk, fat, protein and milksolids are shown on (Table 1). Milk and protein yields per cow were highest in FNWest, while cows in KIsland produced the least milk, fat, protein and milksolids yields and had the highest SCC. The difference in milk yield/cow between the dairy locations in the north-west (FNWest and NWest) and the NEast was 98 L, the difference in milk yield between all the northern locations and the South was 697L. Dairy herds in mainland Tasmania out-produced herds in KIsland by 1274 L of milk, 48 kg of fat and 44 kg of protein per cow per year. Milk fat and milksolids yields were highest in CntNorth and FNWest.

*Herd Size.* Significant variation in milk production due to differences in herd size was observed. Cows in Very Large herds produced the most milk, fat, protein and milksolids while Medium herds produced the least milk and protein yields (Table 1). Milk fat yield and average SCC did not differ between cows in Medium and Small herds. Cows in the Small and Large herds had the highest and lowest SCC respectively.

*Calving Season.* Spring-calving cows produced significantly more milk, fat, protein and milksolids than Autumn and Summer-calving cows (Table 1). On the other hand, SCC was highest in Summer-calving cows and lowest in Autumn-calving cows. Milk yield difference between Spring and Autumn-calving cows was 676 litres, while fat and protein

yields between cows calving in both seasons differed by approximately 25 kg. Daily milk, fat, protein and milksolids yields followed the same trend.

*Insert Table 2 here*

Combined effect and interaction between breed and calving year—interaction.

Least squares means for combinations of breed and calving year are shown in Table 2. The differences in total milk, fat and protein yields/cow between were significantly lower in JJ compared with FF and FJ breeds. Within all breeds, total milk yield increased in all calving years except 2003 when it fell. In all calving years, FF cows produced the most milk and JJ the least. The general decrease in total milk yield in 2003 was lower in FF cows compared to FJ and JJ breeds. The subsequent recovery and increase in milk yield in 2004 was 353L in FJ compared with 288L and 149L in FF and JJ breeds, respectively. Although fat and protein production patterns were similar among the breeds across calving years, gains between years were slightly lower in JJ compared with the other breeds. SCC increased during the calving year 2001 to 2002 in FJ and FF breeds, but declined in JJ breed. No interaction effects were detected between breed and calving years for daily milk and milksolids yields. In contrast, the difference in total milk yield between FF and FJ for all calving years averaged 958 L, while that between FF and JJ averaged 1497 L. Similarly, the differences in protein yields between FF vs FJ and FF vs JJ were 20 kg and 28 kg, respectively.

Milk yield (L) differences between the highest and lowest calving years for each breed were: 818, 786, and 352 for FF, FJ and JJ breeds respectively. Milk fat yield declined by between 3 and 4 kg in FF and JJ breeds from 2002 to 2003, but increased by 1 kg in FJ during the same period. JJ cows produced more fat than FJ in 2000 to 2002, both produced equal

amounts of fat in 2003 but the FJ produced more fat than Jerseys in the subsequent calving years. Of all the breeds, only the FJ produced more fat in 2003 than in 2002. Milk protein yield was similar between JJ and FJ breeds in 2000-2002 but the latter produced 6-15 kg more milk protein in 2003-2005. Milk protein yield was lower although not significantly ( $P>0.05$ ) in 2002 than 2003 in all breeds except FJ. The FF breed produced milk with higher SCC in 2000-2001 than the other breeds while FJ produced milk with the highest SCC in 2002-2005.

Combined effect and interaction between calving year and calving season interaction. Milk yield/lactation for all years averaged 4845, 4463, 4249 and 4094 for spring, winter, summer and autumn calving cows, respectively. Reduction in total milksolids in autumn and summer-calving cows, due to the drought of 2003 were 7.5 and 18.2 kg respectively, while spring and winter-calving cows produced 8 and 11 kg more milksolids during the same year. With the exception of spring-calving cows in 2002, 2004 and 2005, SCC was highest in summer-calving cows and lowest in autumn calvers.

Combined effect and interaction between breed and calving season interaction. Least squares means for combinations of breed and calving season is shown in Table 2. FF cows produced the most milk and milk components in all calving seasons and years. Total milk yield per lactation was lowest in autumn-calving JJ cows. In contrast, milk fat yield was highest in JJ and FJ cows that calved in spring and lowest in autumn calvings in all breeds. FF cows that calved during autumn and spring produced the most milk protein and milk solids, while autumn-calving JJ cows produced the least. SCC was highest in FJ cows that calved during summer and lowest in autumn calvings.

DATA2

Unadjusted means of total milk, fat and protein yields (Table 3) were highest in third and lowest in first parity FF cows. Log of SCC were similar across parities. Parity three FF cows produced 651 L more milk at 305 day than their second parity counterparts while the latter produced 661 L more milk than the first parity cows. Mean 305 day milk fat and protein yields were highest in autumn calving FF cows. Milk yield was lowest in spring-calving cows while fat and protein yields were lowest in summer calvers. Holstein Friesian cows calving in autumn produced 614 L more milk than those that calved in winter. Winter-calving cows produced 185 and 105 L more milk at 305d than those calving in spring and summer respectively. Autumn calving FF cows produced 7% and 10% more total fat and protein respectively, than their winter-calving counterparts, but the difference between summer and spring calving cows was marginal.

Milk, fat and protein yields per cow increased annually from 2000 to 2005 except for a slight production dip in 2002. Average annual rates of increase in yields were 3%, 3% and 4% for milk, fat and protein respectively. Milk and protein yields/cow were highest in the NWest, followed by FNWest and lowest in KIsland. On the other hand, FF cows in the CntNorth produced the highest quantity of milk fat followed by cows in the NWest and FNWest with cows in the KIsland again producing the least. The difference in milk yield/cow between the highest and the lowest producing locations was 1376 L. Fat and protein yields (kg/cow) differed less dramatically and ranged between 237-202 and 195–152, respectively. Somatic cell counts were similar between parity groups, production years and locations.

*Insert Table 3 here*

*Heritability, genetic and phenotypic correlations of production traits*

Heritability of 305d milk in FF cows was highest followed by that of 305d fat yield while  $h^2$  of SCC was lowest. Phenotypic correlations among production traits ranged from 0.66 (milk vs. fat) to 0.92 (milk vs. protein) while that between production traits and SCC ranged from -0.03 (protein vs. SCC) to -0.05 for SCC vs. fat (Table 4). Phenotypic correlation between fat and protein was higher than that between milk and fat. Similarly, genetic correlation was highest between milk and protein being 0.85 and lowest between fat and SCC at 0.03. Phenotypic correlations between the milk, fat and protein yields were generally higher than the corresponding genetic correlations.

*Insert Table 4 here*

## **DISCUSSION**

### *Goodness of model fitting*

The model fitted explained between 42-45% of the variation due to the factors tested for all traits considered in the study (Table 1). This would imply that there were other unaccounted explanatory variables beyond the scope of the fitted model. Such variables would include temporary environmental factors like feed intake, feed quality, milking frequency, housing condition, diseases and other management factors. These details about herd management were not available in the data used in this study. It has been reported that management factors due to individual farmer experience and openness to adoption of scientific and technological tools can have tremendous impact on dairy cow productivity even when animals of similar breed and production merit have been used (Chapman *et al.* 2004). The results of this study should therefore be interpreted in the light of the available data and tested factors.

360 *Calving year, calving season and their interactions*

361 Total yields of milk, fat and protein in this study were higher than the values reported for low-  
362 and high-bodyweight Holstein-Friesian cows in New-Zealand (Lopez *et al.* 2001), but lower  
363 than the values reported by Bargo *et al.* (2002) and García *et al.* (1998; 2007) for high merit  
364 cows on pasture allowance and concentrate supplementation in individual vs. group feeding  
365 trials, respectively. Our results on total milk yield per lactation were however in agreement  
366 with the findings of Grainger (1990) and García and Holmes (2001). The latter reported  
367 average milk yields ranging from 4982-5409 L, s.e.=85.7 in autumn and spring-calving FF  
368 cows. The higher responses in milk yield and milk component yields under experimental  
369 conditions compared with aggregate data emanating from large number of cows from multiple  
370 herds over diverse locations were expected. For instance, Bargo *et al.* (2002) and García *et al.*  
371 (2007), offered concentrate at 1kg/4kg milk yield and 3-7kg as fed/cow/day to twenty-four  
372 and fifty grazing cows respectively, whereas we evaluated data on 103,366 cows. Figures on  
373 annual increases in milk yield in this study were generally lower than the national averages  
374 (Dairy Australia 2006, DPIW 2005), but annual milk yields in 2000 to 2001 and 2003 to 2004  
375 (Table 1) were well in agreement with published figures. The restriction of our data sets to  
376 production records of only three genotypes could partly account for the discrepancy with the  
377 national figures. Furthermore, differences in milk yield per cow due to higher use of  
378 concentrate feeds in the states of Victoria and New South Wales (Dairy Australia 2006) may  
379 also partly explain the lower milk and component yields in Tasmania. The decline in  
380 production in 2002/03 calving season was attributed to feed shortages from the severe and  
381 widespread drought of that season. Climatic factors such as low rainfall and adverse  
382 temperatures have negative effect on milk yield in temperate cows through the  
383 physiologically induced depressed feed intake (Msanga *et al.* 2000). Analysed climatic data  
384 (Geography of Tasmania 2008) showed that maximum temperature was significantly lower



( $P<0.05$ ) in 2004 than in other years, while mean annual rainfall was  $612.2\pm33.9$  mm in 2002 to 2003 calving season compared with 780.4 mm in other years. Reduced rainfall could depress pasture dry matter (DM) yield and metabolisable energy (ME) content, thus reducing energy intake and productivity of pasture-based cows (Walker *et al.* 2004). Differences in milk yield between calving years have been reported (Dairy Australia 2005, Msanga *et al.* 2000). Unlike in this study, White *et al.* (2002) found no significant interactions between calving season and other factors.

Our results are also in agreement with seasonal variations in milk and milksolids yields reported by García *et al.* (1998) for pasture-based cows. They reported that autumn-calving FF cows produced significantly more milksolids than spring-calving FF cows due to the effect of lush pasture with higher ME in spring (spring hump) and extended lactation due to greater persistency. Typically, dairy cows attain peak yields between 3-8 weeks *postpartum* (Tekerli *et al.* 2000). In pasture-based, winter-calving systems, it has been reported that the peak month of milk production coincides with spring when production almost doubled that of the lowest months between May and July (Edward 2005). Our findings revealed that lactation length was significantly longer ( $p<0.05$ ) in autumn-calving, compared with spring-calving FF cows ( $306\pm0.34$  v.  $269\pm0.16$  days). On the other hand, White *et al.* (2002) reported that autumn and spring-calving cows had similar milksolids yields in northern Victoria. Differences in production traits during different calving season reflect seasonal variations in diverse calving systems practiced all over Australia aimed at minimising feed cost by matching peak nutrient requirement for lactation with the period of highest availability of ME from pastures (Walker *et al.* 2004). Although most farms practice split calving system, percentage calving patterns of dairy herds in Tasmania were 51% and 38% for winter and spring calvings, respectively.

*Breed*

Milk yield/lactation of FF cows reported in this study was comparatively lower than the performance of the North American FF strains but similar with the milk, fat and protein yields of New Zealand strains reported in the study by Horan *et al.* (2005) who also found that the mean pedigree index for milk yield was significantly higher in North American strains compared with the New Zealand strains. Our results were also similar to the findings of Dobos *et al.* (2001) in pasture-based FF heifers over three lactations and the report of White *et al.* (2002) in which Jersey cows produced 23.3% less milk than Holsteins.

Total milksolids yields obtained in this study was higher than the values reported for FF cows in New Zealand (García *et al.* 1998, and Lopez *et al.* 2001). Their study evaluated two strains of FF cows bred for low and high body weights, under low stocking rates (1.95-2.25 cows/ha) supplemented with 0.4-1.20 ton DM/cow concentrate. Average stocking rate in dairy farms in Australia is about 2.5 cows/ha (Dairy Australia 2005). Poor efficiency of grain supplement utilisation due to higher level of substitution under low stocking rates or high pasture allowance has been reported in literature (Robaina *et al.* 1998, Stockdale 1999 and Fulkerson *et al.* 2000). The daily milksolids yield reported herein are in agreement with the findings of Bryant *et al.* (2003) who utilised FF cows at a stocking rate of 4.4 cows/ha and supplemented with 1.3-1.5 t DM per annum for three seasons.

The higher performance of FJ over the JJ cows demonstrated the beneficial effect of heterosis. The rate of genetic progress in the dominant dairy breeds was evident in the annual rate of increase in milk and constituent yields. Whereas increase in milk yield/lactation averaged 5% and 5.3% in FF and FJ breeds respectively, it was 3% in JJ. In addition, the percentage

decline in lactation in 2003 was 1.7% in FF while it was 2.7% in FJ and JJ. Madgwick and Goddard (1989) had highlighted the possibility of slower genetic progress which might make Jersey cows less competitive in the future.

#### *Parity*

Milk production is known to increase with increase in parity and cow age due to higher body weight, larger capacity for dry matter intake, increase in size of the udder and recurrence of pregnancy and lactations (Capuco *et al.* 2001). Lower production in primiparous cows is related to competition between tissues (e.g. mammary gland v. peripheral tissues) for metabolites for growth and lactation in the immature animal (Teklerli *et al.* 2000). Similar observations to our study on the effect of parity on dairy cow performance has also been reported (Val-Arreola *et al.* 2004).

#### *Location*

Milk yield per cow in 2002/03 calving season obtained in this study was higher than reported averages in other states of Australia, except Western Australia and South Australia. Production per cow in Tasmania was lower than that of other states except Queensland in 2003/04 (Dairy Australia 2005). Concerns over low production per cow *vis-a-vis* increasing use of grain concentrates to benefit from increasing genetic potential of dairy cows is a main issue in pasture-based dairying (Chapman *et al.* 2004). In 2001, the Australian Dairy Herd Improvement Scheme (ADHIS) adopted the Australian Profit Ranking (APR) method for sire breeding value evaluation as a measure of improving long term productivity and profit per cow. Pasture-based dairying in Tasmania is also focussing on production per hectare as a measure of farm productivity rather than productivity per cow *per se* as evidence from industry reports show that the link between profit and pasture utilisation is the strongest of all

performance indicators (Dairy Australia, 2004). Differences in yield traits between locations, attributable to differences in the rainfall distribution pattern and geo-physical conditions, have been reported extensively in literature (Msanga *et al.* 2000, Horan *et al.* 2005, Dairy Australia 2005). A review of climate data in the study area showed that mean annual rainfall and altitude were significantly different ( $p<0.001$ ) between the dairying locations in Tasmania. Mean annual rainfall was lower in the South but significantly higher ( $p<0.01$ ) in King Island compared to the other location. Mean altitude (meters above sea level) averaged  $117.7\pm16.4$  m in Central North, North West, North-East and Far North-West locations compared with an average of 43.6m in the South and king Island. (Geography of Tasmania 2008). In addition, considerable investment undertaken in the North-West and North-East areas of the state in the last decade has encouraged the emergence of corporate farmers with large herds with the attendant economies of scale (DPIW 2005). It should be noted however that the relatively smaller number of cows (Table 1) in the South and king Island could have some bearing on some of the responses evaluated in these location.

#### *Herd size*

Herd sizes reported in this study were generally consistent with the national dairy herd statistics (Dairy Australia 2006). Tasmania has the highest mean herd size of 254 cows per herd, while Queensland has the smallest with 158 cows per herd. Higher performance in herds with large number of cows is also in agreement with results from dairying in Victoria. A benchmark study in Western Victoria that compared profitability indices of the top and bottom 10 farms indicated that large herds were more profitable and gave greater returns on capital than medium or small herds. As herd size increases, overhead and labour costs can be spread over more units (Doyle and Kelly 1998). In addition, owners of larger herds have been reported to adopt high intensity feeding systems and appeared more open to improved

management systems than small or medium herd owners (DRDC 1996). Smaller herds, on the other hand can benefit from the flexibility in land and labour management to increase per unit resource (Doyle and Kelly 1998).

#### *Heritability of milk, fat and protein yields.*

The relatively small size data used in this study could lead to an over-estimation of the  $h^2$  estimates. It is known that the greater the sample size, the higher the precision of additive genetic estimates (Jensen 2001). However, our  $h^2$  estimates using both univariate and multivariate approaches were within the range of values reported in literature which ranged from 0.31, (Wilmink 1987) to 0.49 (Pander *et al.* 1992). Meyer *et al.* (1989) compared the different methods of estimating  $h^2$  and reported 305-day milk yield  $h^2$  of 0.37. In another study that compared alternative methods of equalizing heterogeneity of variance, Boldman and Freeman (1990) reported lower  $h^2$  estimates of 0.18, 0.22, and 0.24 for untransformed milk yield in low, medium, and high producing herds, respectively. Heritability estimates of fat and protein yields reported in this study were slightly higher than the values reported by Visscher and Goddard (1995) from five states of Australia (excluding Tasmania), probably partly because they used test-day sire models in their evaluation while we utilised an animal model with 305-day records. However, our results were in agreement with the work of Swalve (1995) who utilised test-day, herd-year-season animal model and reported 305d milk, fat and protein  $h^2$  estimates of 0.39, 0.32 and 0.30 respectively.

Comparison of  $h^2$  estimation methods showed that test-day approaches generally yield lower estimates, (Meyer *et al.* 1989, Pander *et al.* 1992) compared with 305-day method. Issues from using aggregated 305-day milk yield and the benefits of test-day random regression models have been extensively reviewed (Jensen 2001). The continuation of using 305-day milk yield stems from industry tradition and the limitations imposed by computations

requirements until recently (Jensen 2001). There is however, a general consensus that the heritabilities for fat were, in almost all cases, lower than the heritabilities for protein, and that milk production has the highest heritability.

## **Conclusions**

This study investigated the influence of genetic and environmental factors affecting dairy production in Tasmania. Breed, parity, age and lactation length, were important determinants of milk and milk solid yields under pasture-based dairy systems. Improved yields over the years were indicative of not only improvement in dairy cow genetics, but also improvement in the adoption of better management practices. Season played a significant role in the calving pattern of pasture-based dairy cows in Tasmania due to the variation in micro climate across the dairy regions. The inclusion of random cow effect in the animal model showed higher yields attributable to additive genetic variance in the FF cows, although small data size precluded the estimation of the additive genetic effects in the other breeds. This would suggest the potential for genetic manipulation to increase yields. Significant herd effect also suggested that there was scope to improve productivity through the adoption of improved management practices. Herd size as a factor of management improved production traits in very large herds thus supporting the emerging trends for larger dairy herds in Tasmania. Other management factors such as access to information and market, favourable market prices, technical and managerial support are very important if farmers are to cope with the challenge of running profitable dairy enterprises. The heritability and genetic and phenotypic correlation estimates in this study fall within the expected ranges in dairy cattle, thus confirming that years of selection of the milking herd in Tasmania will likely continue to improve genetic progress within the pasture-based dairy framework. A desirable future goal would be to conduct a comparative economic analysis of farm profitability under high grain

supplementation versus grazing only to shed more light on the cost-effective benefits of pasture-based dairying.

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Table 1. Least squares means $\pm$ s.e. of total milk, fat, protein yields per lactation and somatic cell count of dairy cows by breed, parity, calving year, locations, herd size, and calving season.

See materials and methods for definition of location and SCC.

Means bearing different superscripts within the same column are statistically different ( $p < 0.01$ )

| Category              | Milk (L)                      | Fat(kg)                    | Protein(kg)                | Milksolids (kg)             | Log SCC *<br>$\times 10^3$  | Milk (L/d)                   | Milksolids<br>kg/d)           | n      |
|-----------------------|-------------------------------|----------------------------|----------------------------|-----------------------------|-----------------------------|------------------------------|-------------------------------|--------|
| <i>Breed</i>          |                               |                            |                            |                             |                             |                              |                               |        |
| Friesian              | 5212 $\pm$ 34.2 <sup>a</sup>  | 210 $\pm$ 1.3 <sup>a</sup> | 171 $\pm$ 1.1 <sup>a</sup> | 380 $\pm$ 2.4 <sup>a</sup>  | 133 $\pm$ 6.4 <sup>a</sup>  | 18.2 $\pm$ 0.11 <sup>a</sup> | 1.33 $\pm$ 0.008 <sup>a</sup> | 82,920 |
| Crossbred             | 4253 $\pm$ 53.7 <sup>b</sup>  | 196 $\pm$ 2.1 <sup>b</sup> | 150 $\pm$ 1.7 <sup>b</sup> | 346 $\pm$ 3.7 <sup>b</sup>  | 135 $\pm$ 10.0 <sup>a</sup> | 14.9 $\pm$ 0.18 <sup>b</sup> | 1.21 $\pm$ 0.012 <sup>b</sup> | 10,001 |
| Jersey                | 3713 $\pm$ 60.0 <sup>c</sup>  | 197 $\pm$ 2.4 <sup>b</sup> | 143 $\pm$ 1.9 <sup>c</sup> | 340 $\pm$ 4.2 <sup>b</sup>  | 127 $\pm$ 11.3 <sup>b</sup> | 13.1 $\pm$ 0.20 <sup>c</sup> | 1.19 $\pm$ 0.014 <sup>b</sup> | 14,059 |
| <i>Parity</i>         |                               |                            |                            |                             |                             |                              |                               |        |
| 1                     | 3482 $\pm$ 53.8 <sup>c</sup>  | 158 $\pm$ 2.1 <sup>c</sup> | 119 $\pm$ 1.8 <sup>c</sup> | 277 $\pm$ 3.7 <sup>c</sup>  | 157 $\pm$ 10.0 <sup>a</sup> | 12.3 $\pm$ 0.18 <sup>c</sup> | 0.98 $\pm$ 0.129 <sup>c</sup> | 26,893 |
| 2                     | 4020 $\pm$ 45.2 <sup>d</sup>  | 184 $\pm$ 1.8 <sup>d</sup> | 141 $\pm$ 1.5 <sup>d</sup> | 326 $\pm$ 3.1 <sup>d</sup>  | 132 $\pm$ 8.5 <sup>b</sup>  | 14.2 $\pm$ 0.15 <sup>d</sup> | 1.15 $\pm$ 0.011 <sup>d</sup> | 22,372 |
| 3                     | 4615 $\pm$ 48.6 <sup>c</sup>  | 212 $\pm$ 1.9 <sup>c</sup> | 164 $\pm$ 1.6 <sup>c</sup> | 376 $\pm$ 3.4 <sup>c</sup>  | 129 $\pm$ 9.1 <sup>c</sup>  | 16.2 $\pm$ 0.17 <sup>c</sup> | 1.31 $\pm$ 0.012 <sup>c</sup> | 18,154 |
| 4                     | 4826 $\pm$ 51.6 <sup>b</sup>  | 222 $\pm$ 2.0 <sup>b</sup> | 172 $\pm$ 1.7 <sup>b</sup> | 393 $\pm$ 3.6 <sup>b</sup>  | 127 $\pm$ 9.7 <sup>c</sup>  | 16.9 $\pm$ 0.18 <sup>b</sup> | 1.37 $\pm$ 0.012 <sup>b</sup> | 15,081 |
| >4                    | 5019 $\pm$ 51.9 <sup>a</sup>  | 228 $\pm$ 2.0 <sup>a</sup> | 179 $\pm$ 1.7 <sup>a</sup> | 407 $\pm$ 3.6 <sup>a</sup>  | 112 $\pm$ 9.8 <sup>d</sup>  | 17.5 $\pm$ 0.18 <sup>a</sup> | 1.42 $\pm$ 0.012 <sup>a</sup> | 24,490 |
| <i>Calving Year</i>   |                               |                            |                            |                             |                             |                              |                               |        |
| 2000                  | 4058 $\pm$ 71.9 <sup>c</sup>  | 184 $\pm$ 2.8 <sup>c</sup> | 140 $\pm$ 2.4 <sup>c</sup> | 325 $\pm$ 5.0 <sup>c</sup>  | 121 $\pm$ 13.5 <sup>c</sup> | 14.3 $\pm$ 0.25 <sup>d</sup> | 1.41 $\pm$ 0.017 <sup>a</sup> | 6,064  |
| 2001                  | 4299 $\pm$ 54.5 <sup>d</sup>  | 196 $\pm$ 2.1 <sup>d</sup> | 150 $\pm$ 1.8 <sup>d</sup> | 346 $\pm$ 3.8 <sup>d</sup>  | 115 $\pm$ 10.2 <sup>d</sup> | 15.1 $\pm$ 0.19 <sup>c</sup> | 1.21 $\pm$ 0.013 <sup>d</sup> | 9,447  |
| 2002                  | 4406 $\pm$ 49.3 <sup>c</sup>  | 200 $\pm$ 1.9 <sup>c</sup> | 153 $\pm$ 1.6 <sup>c</sup> | 353 $\pm$ 3.4 <sup>c</sup>  | 125 $\pm$ 9.2 <sup>c</sup>  | 15.4 $\pm$ 0.17 <sup>c</sup> | 1.23 $\pm$ 0.012 <sup>d</sup> | 13,334 |
| 2003                  | 4305 $\pm$ 44.9 <sup>d</sup>  | 198 $\pm$ 1.8 <sup>d</sup> | 153 $\pm$ 1.5 <sup>c</sup> | 352 $\pm$ 3.1 <sup>c</sup>  | 137 $\pm$ 8.4 <sup>b</sup>  | 15.1 $\pm$ 0.15 <sup>c</sup> | 1.23 $\pm$ 0.011 <sup>d</sup> | 18,332 |
| 2004                  | 4577 $\pm$ 43.4 <sup>b</sup>  | 209 $\pm$ 1.7 <sup>b</sup> | 164 $\pm$ 1.4 <sup>b</sup> | 373 $\pm$ 3.0 <sup>b</sup>  | 135 $\pm$ 8.1 <sup>b</sup>  | 16.0 $\pm$ 0.15 <sup>b</sup> | 1.31 $\pm$ 0.010 <sup>c</sup> | 25,250 |
| 2005                  | 4710 $\pm$ 41.2 <sup>a</sup>  | 216 $\pm$ 1.6 <sup>a</sup> | 169 $\pm$ 1.4 <sup>a</sup> | 385 $\pm$ 2.9 <sup>a</sup>  | 156 $\pm$ 7.7 <sup>a</sup>  | 16.5 $\pm$ 0.14 <sup>a</sup> | 1.34 $\pm$ 0.009 <sup>b</sup> | 34,563 |
| <i>Location</i>       |                               |                            |                            |                             |                             |                              |                               |        |
| FNWest                | 4879 $\pm$ 25.8 <sup>a</sup>  | 220 $\pm$ 1.0 <sup>a</sup> | 172 $\pm$ 0.8 <sup>a</sup> | 391 $\pm$ 1.8 <sup>a</sup>  | 119 $\pm$ 4.8 <sup>c</sup>  | 16.9 $\pm$ 0.09 <sup>a</sup> | 1.36 $\pm$ 0.006 <sup>a</sup> | 52,771 |
| NWest                 | 4498 $\pm$ 27.2 <sup>c</sup>  | 206 $\pm$ 1.1 <sup>c</sup> | 159 $\pm$ 0.9 <sup>c</sup> | 365 $\pm$ 1.9 <sup>c</sup>  | 129 $\pm$ 5.1 <sup>b</sup>  | 15.8 $\pm$ 0.09 <sup>b</sup> | 1.28 $\pm$ 0.006 <sup>b</sup> | 25,574 |
| CntNorth              | 4814 $\pm$ 31.8 <sup>b</sup>  | 220 $\pm$ 1.3 <sup>a</sup> | 170 $\pm$ 1.0 <sup>b</sup> | 392 $\pm$ 2.2 <sup>a</sup>  | 124 $\pm$ 60.0 <sup>b</sup> | 16.7 $\pm$ 0.11 <sup>a</sup> | 1.36 $\pm$ 0.008 <sup>c</sup> | 4,931  |
| South                 | 4047 $\pm$ 60.5 <sup>d</sup>  | 183 $\pm$ 2.4 <sup>d</sup> | 143 $\pm$ 2.0 <sup>d</sup> | 326 $\pm$ 4.2 <sup>d</sup>  | 119 $\pm$ 11.4 <sup>c</sup> | 14.3 $\pm$ 0.21 <sup>c</sup> | 1.15 $\pm$ 0.014 <sup>d</sup> | 659    |
| NEast                 | 4786 $\pm$ 26.8 <sup>b</sup>  | 213 $\pm$ 1.1 <sup>b</sup> | 168 $\pm$ 0.9 <sup>b</sup> | 382 $\pm$ 1.9 <sup>b</sup>  | 119 $\pm$ 4.8 <sup>c</sup>  | 16.7 $\pm$ 0.09 <sup>a</sup> | 1.33 $\pm$ 0.006 <sup>a</sup> | 26,997 |
| KIsland               | 3331 $\pm$ 178.2 <sup>e</sup> | 160 $\pm$ 7.0 <sup>e</sup> | 118 $\pm$ 5.9 <sup>e</sup> | 277 $\pm$ 12.4 <sup>c</sup> | 178 $\pm$ 33.4 <sup>a</sup> | 11.9 $\pm$ 0.61 <sup>d</sup> | 0.99 $\pm$ 0.042 <sup>e</sup> | 1058   |
| <i>Herd Size</i>      |                               |                            |                            |                             |                             |                              |                               |        |
| Small                 | 4485 $\pm$ 52.4 <sup>b</sup>  | 196 $\pm$ 2.0 <sup>c</sup> | 155 $\pm$ 1.7 <sup>b</sup> | 350 $\pm$ 3.6 <sup>b</sup>  | 142 $\pm$ 9.8 <sup>a</sup>  | 15.9 $\pm$ 0.18 <sup>b</sup> | 1.23 $\pm$ 0.013 <sup>b</sup> | 1,487  |
| Medium                | 4141 $\pm$ 41.6 <sup>d</sup>  | 195 $\pm$ 1.6 <sup>c</sup> | 148 $\pm$ 1.4 <sup>d</sup> | 343 $\pm$ 2.9 <sup>c</sup>  | 130 $\pm$ 7.8 <sup>a</sup>  | 14.5 $\pm$ 0.14 <sup>d</sup> | 1.20 $\pm$ 0.010 <sup>c</sup> | 5,766  |
| Large                 | 4271 $\pm$ 39.3 <sup>c</sup>  | 200 $\pm$ 1.5 <sup>b</sup> | 151 $\pm$ 1.3 <sup>c</sup> | 350 $\pm$ 2.7 <sup>b</sup>  | 122 $\pm$ 7.4 <sup>b</sup>  | 15.0 $\pm$ 0.13 <sup>c</sup> | 1.23 $\pm$ 0.009 <sup>b</sup> | 28,228 |
| Very large            | 4672 $\pm$ 39.2 <sup>a</sup>  | 212 $\pm$ 1.5 <sup>a</sup> | 166 $\pm$ 1.3 <sup>a</sup> | 378 $\pm$ 2.7 <sup>a</sup>  | 131 $\pm$ 7.4 <sup>a</sup>  | 16.4 $\pm$ 0.13 <sup>d</sup> | 1.32 $\pm$ 0.009 <sup>a</sup> | 71,509 |
| <i>Calving Season</i> |                               |                            |                            |                             |                             |                              |                               |        |
| Spring                | 4770 $\pm$ 34.5 <sup>a</sup>  | 215 $\pm$ 1.4 <sup>a</sup> | 168 $\pm$ 1.1 <sup>a</sup> | 383 $\pm$ 2.4 <sup>a</sup>  | 139 $\pm$ 6.5 <sup>b</sup>  | 16.6 $\pm$ 0.12 <sup>a</sup> | 1.34 $\pm$ 0.004 <sup>c</sup> | 40,185 |
| Summer                | 4249 $\pm$ 94.4 <sup>c</sup>  | 190 $\pm$ 3.7 <sup>c</sup> | 148 $\pm$ 3.1 <sup>c</sup> | 338 $\pm$ 6.6 <sup>c</sup>  | 146 $\pm$ 6.7 <sup>a</sup>  | 14.8 $\pm$ 0.32 <sup>c</sup> | 1.18 $\pm$ 0.023 <sup>c</sup> | 1,584  |
| Autumn                | 4094 $\pm$ 42.4 <sup>c</sup>  | 189 $\pm$ 1.7 <sup>c</sup> | 144 $\pm$ 1.4 <sup>c</sup> | 333 $\pm$ 2.9 <sup>c</sup>  | 112 $\pm$ 8.0 <sup>d</sup>  | 14.6 $\pm$ 0.15 <sup>c</sup> | 1.18 $\pm$ 0.010 <sup>c</sup> | 10,130 |
| Winter                | 4457 $\pm$ 33.7 <sup>b</sup>  | 208 $\pm$ 1.3 <sup>b</sup> | 160 $\pm$ 1.1 <sup>b</sup> | 368 $\pm$ 2.3 <sup>b</sup>  | 129 $\pm$ 6.3 <sup>c</sup>  | 15.6 $\pm$ 0.12 <sup>b</sup> | 1.29 $\pm$ 0.008 <sup>b</sup> | 55,091 |

Table 2. Least square means of interactions of breed, calving year and calving season for milk, fat, protein and somatic cell count of three dairy cows breeds in Tasmania.

See materials and methods for definition of SCC. All tested factors were significant (P<0.01)

| Category              | Milk (L)   | Fat(kg) | Protein(kg) | Milksolids (kg) | Log SCC <sup>*</sup> x10 <sup>3</sup> | Milk (L/d) | Milksolids kg/d) | n     |
|-----------------------|------------|---------|-------------|-----------------|---------------------------------------|------------|------------------|-------|
| <i>Breed x Year</i>   |            |         |             |                 |                                       |            |                  |       |
| Crossbred - 2000      | 3824±97.1  | 175±3.8 | 134±3.2     | 308±6.73        | 124±18.2                              | 13.5±0.33  | 1.09±0.023       | 515   |
| Crossbred - 2001      | 4095±76.7  | 187±3.0 | 143±2.5     | 330±5.32        | 109±14.4                              | 14.5±0.26  | 1.16±0.018       | 804   |
| Crossbred – 2002      | 4278±68.9  | 193±2.7 | 149±2.3     | 342±4.78        | 135±12.9                              | 14.9±0.24  | 1.19±0.016       | 1173  |
| Crossbred - 2003      | 4164±62.3  | 194±2.4 | 149±2.1     | 343±4.79        | 140±11.7                              | 14.6±0.21  | 1.20±0.015       | 1827  |
| Crossbred - 2004      | 4547±58.9  | 210±2.3 | 164±1.9     | 373±4.09        | 134±11.1                              | 15.9±0.20  | 1.30±0.014       | 2518  |
| Crossbred - 2005      | 4609±56.1  | 215±2.2 | 165±1.9     | 380±3.89        | 167±10.5                              | 16.1±0.19  | 1.32±0.013       | 3174  |
| Friesian - 2000       | 4801±66.2  | 193±2.6 | 153±2.2     | 346±4.59        | 131±12.4                              | 16.8±0.23  | 1.21±0.016       | 4786  |
| Friesian – 2001       | 5147±47.7  | 206±1.8 | 167±1.6     | 372±3.30        | 120±8.9                               | 17.9±0.16  | 1.30±0.016       | 7442  |
| Friesian – 2002       | 5197±43.2  | 210±1.6 | 168±1.4     | 377±2.99        | 124±8.11                              | 18.1±0.15  | 1.31±0.010       | 10499 |
| Friesian – 2003       | 5109±39.2  | 206±1.5 | 169±1.3     | 374±2.72        | 133±7.3                               | 17.9±0.13  | 1.30±0.009       | 13929 |
| Friesian - 2004       | 5397±37.7  | 218±1.4 | 181±1.2     | 398±2.62        | 136±7.07                              | 18.8±0.13  | 1.39±0.009       | 19296 |
| Friesian - 2005       | 5619±35.2  | 226±1.3 | 188±1.1     | 413±2.45        | 155±6.6                               | 19.5±0.12  | 1.44±0.008       | 26968 |
| Jersey - 2000         | 3550±92.2  | 186±3.6 | 134±3.0     | 320±6.39        | 109±17.3                              | 12.5±0.32  | 1.12±0.022       | 763   |
| Jersey – 2001         | 3655±77.7  | 194±3.1 | 141±2.6     | 335±5.39        | 119±14.5                              | 12.9±0.27  | 1.18±0.019       | 1201  |
| Jersey – 2002         | 3742±71.   | 197±2.8 | 142±2.4     | 340±4.96        | 117±13.4                              | 13.2±0.24  | 1.19±0.017       | 1662  |
| Jersey – 2003         | 3640±66.4  | 195±2.6 | 143±2.2     | 337±4.61        | 138±12.5                              | 12.9±0.23  | 1.18±0.159       | 2576  |
| Jersey – 2004         | 3789±64.7  | 201±2.5 | 148±2.1     | 349±4.49        | 134±12.1                              | 13.4±0.22  | 1.22±0.015       | 3436  |
| Jersey – 2005         | 3902±62.8  | 208±2.5 | 153±2.1     | 361±4.36        | 145±11.8                              | 13.8±0.22  | 1.27±0.015       | 4421  |
| <i>Breed x Season</i> |            |         |             |                 |                                       |            |                  |       |
| Crossbred - Autumn    | 3900±68.3  | 182±2.6 | 138±2.3     | 319±4.74        | 103±12.8                              | 13.9±0.23  | 1.13±0.016       | 542   |
| Crossbred - Spring    | 4764±41.4  | 216±1.6 | 168±1.4     | 384±2.87        | 141±7.8                               | 16.6±0.14  | 1.35±0.009       | 3325  |
| Crossbred – Summer    | 3851±156.6 | 172±6.1 | 134±5.1     | 307±10.9        | 164±29.4                              | 13.4±0.54  | 1.07±0.037       | 85    |
| Crossbred - Winter    | 4498±38.4  | 213±1.5 | 162±1.3     | 374±2.66        | 131±7.2                               | 15.8±0.13  | 1.31±0.009       | 6059  |
| Friesian - Autumn     | 5368±36.8  | 199±2.3 | 177±1.2     | 395±2.55        | 121±6.9                               | 18.7±0.13  | 1.38±0.009       | 8647  |
| Friesian - Spring     | 5310±59.1  | 216±1.4 | 175±1.1     | 389±2.31        | 143±6.3                               | 18.6±0.11  | 1.36±0.008       | 32145 |
| Friesian – Summer     | 5094±59.2  | 213±1.3 | 163±1.9     | 362±4.10        | 129±11.1                              | 17.6±0.20  | 1.26±0.041       | 1448  |
| Friesian - Winter     | 5074±33.4  | 208±1.3 | 169±1.1     | 377±2.31        | 140±6.3                               | 17.7±0.11  | 1.32±0.008       | 40680 |
| Jersey - Autumn       | 3014±55.9  | 168±2.2 | 117±1.8     | 285±3.88        | 113±10.5                              | 11.1±0.19  | 1.02±0.013       | 941   |
| Jersey - Spring       | 4235±38.9  | 217±1.5 | 161±1.3     | 378±2.69        | 133±7.3                               | 14.6±0.13  | 1.31±0.009       | 4715  |
| Jersey – Summer       | 3802±196.7 | 200±7.7 | 147±6.5     | 347±13.7        | 144±36.9                              | 13.5±0.67  | 1.20±0.047       | 51    |
| Jersey - Winter       | 3800±36.5  | 203±1.4 | 148±1.2     | 352±2.53        | 117±6.9                               | 13.4±0.13  | 1.23±0.009       | 8352  |

**Table 3.** Descriptive statistics of 305d milk, fat, protein and SCC of Holstein Friesian cows adjusted for terms in the animal model based on DATA2.

See materials and methods for definition of locations and SCC.

<sup>#</sup>Parity >2 were pooled and labelled as parity 3

| Category                    | Milk (L) |      |      |       | Fat (kg) |       |     |     | Protein (kg) |       |     |     | Log of SCC <sup>*</sup> |       |      |      | n     |
|-----------------------------|----------|------|------|-------|----------|-------|-----|-----|--------------|-------|-----|-----|-------------------------|-------|------|------|-------|
| <i>ParityI<sup>#</sup></i>  | Mean     | SD   | Min  | Max   | Mean     | SD    | Min | Max | Mean         | SD    | Min | Max | Mean                    | SD    | Min  | Max  | n     |
| 1                           | 4859     | 1440 | 1209 | 12997 | 196.6    | 52.88 | 18  | 509 | 161.6        | 48.65 | 22  | 469 | 3.83                    | 0.976 | 0    | 8.23 | 18767 |
| 2                           | 5520     | 1647 | 1247 | 13550 | 223.6    | 60.35 | 25  | 480 | 186.1        | 55.57 | 38  | 450 | 3.90                    | 1.061 | 0    | 8.53 | 15677 |
| 3                           | 6171     | 1746 | 1207 | 15141 | 250.6    | 66.12 | 27  | 544 | 207.9        | 57.93 | 16  | 487 | 4.29                    | 1.163 | 0    | 8.94 | 31470 |
| <i>Calving Season</i>       |          |      |      |       |          |       |     |     |              |       |     |     |                         |       |      |      |       |
| Winter                      | 5648     | 1613 | 1207 | 14924 | 231.6    | 62.22 | 18  | 544 | 190.7        | 54.59 | 16  | 487 | 4.05                    | 1.089 | 0    | 8.94 | 32998 |
| Spring                      | 5463     | 1825 | 1210 | 14946 | 219.1    | 66.37 | 25  | 517 | 182.3        | 60.62 | 34  | 468 | 4.12                    | 1.134 | 0    | 8.53 | 24600 |
| Summer                      | 5542     | 1931 | 1296 | 12944 | 218.1    | 73.53 | 43  | 460 | 179.7        | 61.9  | 39  | 414 | 3.89                    | 1.535 | 0    | 7.28 | 1230  |
| Autumn                      | 6262     | 1762 | 1230 | 15141 | 251.8    | 68.15 | 38  | 527 | 210.9        | 60.38 | 40  | 467 | 3.98                    | 1.024 | 0    | 8.06 | 7086  |
| <i>Calving Year</i>         |          |      |      |       |          |       |     |     |              |       |     |     |                         |       |      |      |       |
| 2000                        | 4844     | 1378 | 1229 | 14946 | 197.5    | 55.03 | 29  | 495 | 157.5        | 44.93 | 22  | 468 | 3.83                    | 1.235 | 0    | 8.47 | 4385  |
| 2001                        | 5436     | 1486 | 1474 | 14199 | 218.1    | 55.90 | 52  | 472 | 178.8        | 47.81 | 49  | 456 | 3.83                    | 1.111 | 0    | 7.60 | 6639  |
| 2002                        | 5251     | 1557 | 1247 | 13112 | 212.6    | 60.81 | 40  | 507 | 172.9        | 51.27 | 34  | 432 | 4.08                    | 1.014 | 0    | 7.82 | 9024  |
| 2003                        | 5510     | 1608 | 1230 | 13861 | 222.5    | 60.86 | 18  | 517 | 185          | 53.01 | 40  | 438 | 4.01                    | 1.079 | 0    | 8.15 | 11677 |
| 2004                        | 5816     | 1699 | 1317 | 14360 | 236.4    | 63.45 | 27  | 509 | 197.6        | 56.83 | 26  | 471 | 4.09                    | 1.120 | 0    | 8.39 | 14774 |
| 2005                        | 6024     | 1929 | 1207 | 15141 | 245.1    | 71.05 | 31  | 544 | 204.8        | 65.06 | 16  | 487 | 4.21                    | 1.109 | 0.69 | 8.94 | 19415 |
| <i>Location<sup>‡</sup></i> |          |      |      |       |          |       |     |     |              |       |     |     |                         |       |      |      |       |
| FNWest                      | 5779     | 1684 | 1209 | 14924 | 234.6    | 63.73 | 18  | 544 | 194.9        | 57.44 | 40  | 487 | 4.02                    | 1.068 | 0    | 8.53 | 17152 |
| Nwest                       | 5897     | 1945 | 1230 | 15141 | 234.9    | 68.15 | 44  | 509 | 196.9        | 62.42 | 41  | 469 | 3.97                    | 1.231 | 0    | 8.35 | 14949 |
| CntNorth                    | 5749     | 1640 | 1229 | 13929 | 237.0    | 66.52 | 29  | 514 | 194.3        | 57.19 | 22  | 435 | 4.13                    | 1.082 | 0    | 8.66 | 12376 |
| South                       | 5231     | 1298 | 1273 | 10024 | 209.2    | 55.3  | 46  | 380 | 174.7        | 43.1  | 44  | 328 | 4.39                    | 0.926 | 2.08 | 8.07 | 1108  |
| Neast                       | 5365     | 1631 | 1207 | 14946 | 216.9    | 62.16 | 27  | 517 | 179.9        | 55.45 | 16  | 468 | 4.12                    | 1.071 | 0.69 | 8.94 | 18596 |
| KIsland                     | 4581     | 1331 | 1210 | 9739  | 202.1    | 62.1  | 52  | 446 | 152.0        | 44.25 | 42  | 346 | 4.21                    | 1.018 | 1.39 | 7.54 | 1733  |

**Table 4.** Heritability, phenotypic and genetic correlations ( $\pm$ se) of milk, fat, protein and somatic cell count of Holstein-Friesian cows

Heritability shown in bold (diagonal), phenotypic correlation and genetic correlation on upper and lower triangles respectively.  
SCC=Somatic cell count

| Trait    | Milk                   | Fat                    | Protein                | Log SCC                |
|----------|------------------------|------------------------|------------------------|------------------------|
| Milk     | <b>0.41</b><br>(0.047) | 0.66<br>(0.003)        | 0.92<br>(0.008)        | -0.047<br>(0.004)      |
| Fat      | 0.41<br>(0.009)        | <b>0.37</b><br>(0.005) | 0.75<br>(0.002)        | -0.05<br>(0.004)       |
| Protein  | 0.85<br>(0.003)        | 0.61<br>(0.007)        | <b>0.35</b><br>(0.005) | -0.03<br>(0.004)       |
| Log SCC* | 0.09<br>(0.013)        | 0.034<br>(0.013)       | 0.098<br>(0.014)       | <b>0.28</b><br>(0.005) |

## Appendix 1: Dairy farm facts in Tasmania

| Parameter/Year                    | 99/00 | 00/01 | 01/02 | 02/03 | 03/04 | 04/05 | 05/06 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Milk production, million litres   | 609   | 590   | 671   | 585   | 590   | 600   | 622   |
| Registered Dairy farms, nos       | 734   | 638   | 612   | 597   | 543   | 507   | 498p  |
| Dairy cow numbers, '000           | 139   | 148   | 134   | 142   | 138   | 135   | 135   |
| Employment; owners and staff, nos | 1,890 | NA    | NA    | 1,700 | NA    | NA    | NA    |
| Gross value of production, \$M    | 133   | 148   | 220   | 151   | 160   | 180p  | NA    |
| Average herd size, cows           | 194   | 231   | 236   | 213   | 245   | 271   | 270   |
| Milk per cow, litres              | 4,381 | 4,177 | 4,646 | 4,304 | 4,219 | 4,497 | 4542  |
| Milk per farm, '000 litres        | 830   | 925   | 1,116 | 980   | 1,089 | 1,183 | NA    |
| Milk fat (%)                      | 4.29  | 4.26  | 4.28  | 4.26  | 4.32  | 4.28  | 4.29  |
| Milk Protein (%)                  | 3.29  | 3.28  | 3.29  | 3.29  | 3.36  | 3.36  | 3.37  |

Adapted from: DPWI 2005, Dairy Australia 2006 p=predicted, NA=Not available